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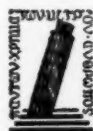
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CHANGES IN HUNGER DURING  
STARVATION

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## CHANGES IN HUNGER DURING STARVATION

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An important problem in the study of behavior is the relation of the degree of hunger to the period of deprivation of food. What is the maximal degree to be obtained during starvation, and how is it related to the degrees prevailing under current experimental procedures of controlling the drive? If the maximal degree can be ascertained, it is possible to express any degree as a percentage of the maximum and hence on an absolute scale. It is then also possible to compare drives associated with different kinds of reinforcement (e.g., sex or thirst).

A convenient measure of hunger in the white rat may be derived from the fact that when a conditioned response is reinforced periodically, the rate at which it is elicited without reinforcement varies with the state of the drive<sup>1</sup>. For example, where the drive is hunger, the rate is modified in a definite way by the ingestion of given amounts of food. The greatest degree of hunger examined in the paper cited was that which prevails just before feeding when a rat is allowed to eat freely for a limited time once a day. The degrees which proved to be dependent upon the ingestion of different amounts of food were below this value, but the rate should also reflect changes in hunger above it.

The procedure of investigating hunger during deprivation is simple. Food is withheld from the organism and the state of the drive measured frequently enough to follow the course of the change with accuracy. The use of a conditional reflex is complicated by the necessity of reinforcing the response to avoid extinction. The reinforcement must involve a consummatory response, and this modifies the drive to some extent. The periodic reinforcement in the present case requires that the organism receive a small amount of food whenever the strength of the drive is measured. The alternative would be to take only one measurement per rat and to obtain the course of the change in terms of the averages for groups deprived of food for different periods. But it will be shown that the rates at which hunger increases during starvation vary quite widely among rats and that an average curve does not reflect the course of the change in the individual case. The first alternative is, therefore, to be preferred even though it does not represent the case for complete deprivation.

\* Manuscript recommended for publication by Dr. J. R. Kantor, April 10, 1937.

<sup>1</sup> Skinner, B. F., *Conditioning and Extinction and their Relation to Drive*, *Jour. Gen. Psychol.*, 1936, 14, 296-317.

The amount of food actually ingested in the present experiment was less than one gram per day and probably had but little effect upon the result.

### SUBJECTS AND TECHNIQUE

Sixteen animals, all males, were started in the experiment. One animal was eliminated very soon because it was found to have defective teeth. The results for two other animals are not included because they were accidentally given access to food. The data which will follow are based upon the remaining thirteen rats.

They were about 150 days of age, with the exception of four which were about 100 days old at the start of the experiment. The subjects were originally grouped in sets of four each. This grouping was maintained throughout the experiment although some of the groups were not full owing to the eliminations mentioned above.

The apparatus and method were essentially as described in the paper cited. The response to be made by the rat was the pressing downward of a light horizontal bar or lever. A clock connected the lever and a food magazine in such a way that a response was reinforced with a small pellet of food every four minutes. All responses were recorded in summation curves. The experimental periods were one hour long and occurred at the same time each day. The first group was started at 8:15 A. M. and the successive groups were run as rapidly as possible, finishing at about 12:30 P. M. The rats were kept in a constant temperature cabinet set at 25° C. Water was available at all times.

On the day previous to the initiation of the starvation period, the rats were allowed continuous access to food for 24 hours. From that time on they were allowed no food save that which was necessary to recondition them. Since the interval of reconditioning was four minutes and the daily test period one hour, each animal received a daily ration of about 15 pellets or a total mass of approximately 0.7 grams.

Under these conditions the animals were tested daily until death by starvation. It was not originally intended to carry the experiment so far as this, but by the time the course of the change had been clearly worked out in each case the animal could not be salvaged.

### RESULTS

In general terms, the results may be stated as follows: As measured by the number of responses to the lever per hour, hunger increases with the period of starvation until a maximal degree is reached. After this point there is a relatively rapid decline in the rate of responding until death ensues from inanition.

Figure 1 is a graph showing the daily mean number of responses. Since there are individual differences in regard to the day on which the maximal rate is reached, the interpretation is somewhat difficult. The rat which reached its maximal rate first did so on the fourth day while at the other extreme one rat prolonged its rise to the thirteenth day after the beginning of the starvation period (see Figure 4). If this difficulty is disregarded and if we assume that there is a direct relationship between the rate of responding and the strength of drive, the mean maximal drive for the group occurred on the fifth day after the beginning of the starvation period.

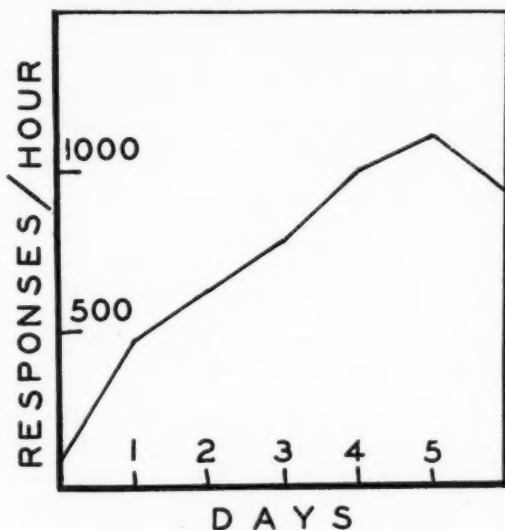


FIGURE 1

*The Change in the Mean Rate of Responding during Starvation.* The point at zero is for the rate after twenty-four hours of continuous access to food. The rate rises rapidly during the first twenty-four hours and continues more slowly but in a roughly linear fashion until a peak is reached on the fifth day. The curve represents thirteen rats. It is not continued after the sixth day because the group was no longer intact.

Figure 1 also indicates that the relationship between the increase in mean drive and the progress of inanition is approximately linear until the peak is reached. The greatest deviation from linearity is the relatively abrupt rise between the first and second points on the curve, but this is an artifact due to the fact that the first period was preceded by a 24-hour period of continuous access to the food.

The curve in Figure 1 has been plotted only to the sixth day after the beginning of starvation. A number of animals continued in the

experiment after this point but several also died before the seventh day's record was taken. It would be misleading to continue this curve since it would no longer be representative of the group as a whole.

Because of the individual differences with respect to the time at which the peak is reached, it was thought desirable to superimpose the individual records at their maximal rates. This was done in the following way. The point of the beginning of the experiment and the point of reaching a peak were indicated on a sheet of graph paper. The distance between them was then divided into a number of equal parts corresponding to the number of days taken to reach the peak by one rat. The data for this rat were then plotted and the points connected by straight lines. The data for each rat were treated in the same way. Ordinates were then erected to divide each of the individual curves into eight equal parts. The intersections of the ordinates with the individual curves were read off on each vertical and averaged. The curves in Figure 2 (solid lines) are for the averages thus obtained. The parts of the curves beyond the peaks were also spaced out on the coordinates assigned to each rat and the averages obtained in the same way. Because of the fact that there was some individual variation in the amount of time elapsing between the attainment of the peak and death, the portions of the curves to the right of the peaks are not representative of the whole group throughout their entire length.

Before the group curves were made by the method described immediately above, the daily records were plotted for each rat. An inspection of the individual curves indicated that it would be convenient to deal with the records in two groups. The first group (A in Figure 2) is composed of the eight animals which rose to their maximal rate and then dropped precipitously back towards zero.

The second group is composed of the remaining five animals, the curve for which is shown as B in Figure 2. They maintained a lower mean rate for the first six-eighths of the time. Their rate from that time on increased more rapidly until they reached a peak, which was not as high as that reached by the first group. Their rate after the peak does not decline so rapidly and their mean survival time is longer.

The differences in these two curves may or may not indicate a fundamental difference in the animals involved. In any case it should be pointed out that the difference after the peak may be an artifact caused by the fact that a continuous process was sampled at the relatively gross intervals of 24 hours. For example, in the rats which are represented in curve B, the drive may have reached its maximal rate in the 24-hour interval elapsing between the test period showing the highest rate and the next test period. In other words, the peak

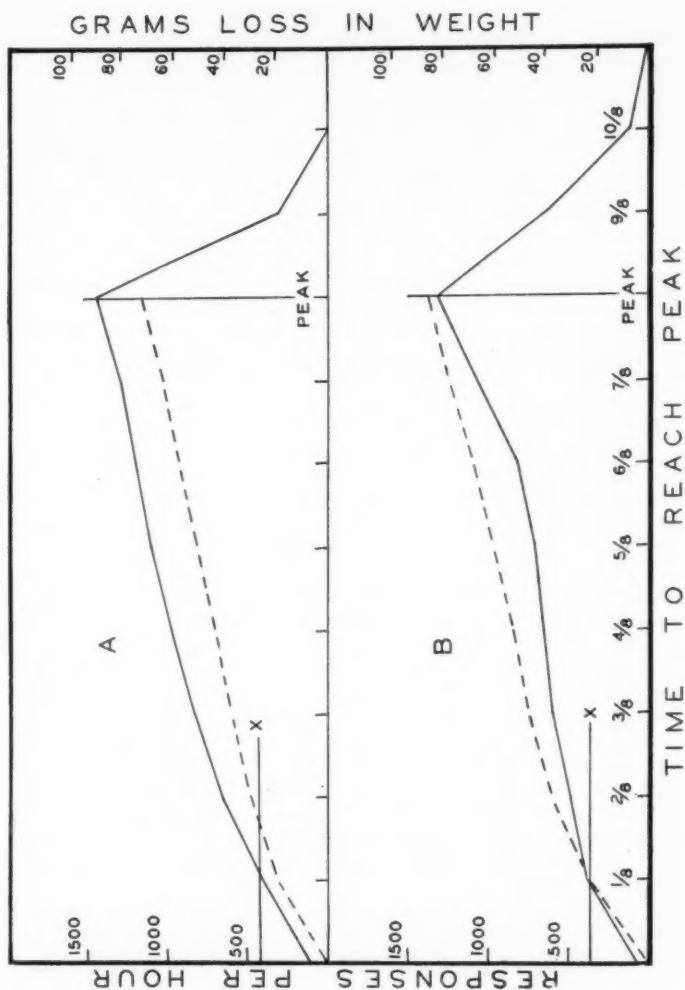


FIGURE 2

The Change in Mean Rate and in Body-Weight when the Individual Series are Superimposed to Bring their Peaks Together. Solid lines: rate; dashed lines: loss in weight. The increase in rate follows the loss in weight fairly closely. Group A (eight rats) shows a more rapid decline after the peak than Group B (five rats). The mean peak is higher and is reached somewhat sooner by Group A. The horizontal lines marked X indicate the rate prevailing at "normal" hunger (see text).

shown on the curve is possibly misplaced to the left of its true position. This difficulty is inherent in the present technique, but it could be minimized by using shorter test periods spaced at closer intervals. After each animal had passed its peak, it was obvious that it was in an extremely impoverished condition. It was cold to the touch (bodily temperatures were not taken), its hair was erect and shaggy, and in many cases a normal posture could not be maintained. From these observations and from the early death of the animal after its peak was reached, it may be possible that the decline in rate of responding was due to physical weakness, rather than to any independent decrease in the state of the drive. The experiments do not confirm the human report of an early decrease in hunger during prolonged fasting.

The two lines drawn parallel with the base line marked X in Figure 2 indicate the rate of response under the usual feeding method<sup>2</sup> as determined for the respective groups before the beginning of the starvation period. It is obvious that the level of drive maintained by the usual feeding method is far below the maximal strength.

The dashed curves in Figure 2 represent the absolute loss in weight for the two groups. Each rat was weighed daily after each test period and the loss of weight calculated. The data thus secured were plotted in the same way as the rates of responding, letting the end point for each rat's weight curve be determined by the day on which he reached his maximal rate of responding. An inspection of Figure 2 shows that the correspondence between the mean loss of weight and the mean rate of responding is very close.

Figure 3 is reproduced to give the reader a photostatic copy of the type of record which is obtained on successive days. The curve at A is the record made by the animal after the 24 hours of continuous access to food. Since the animal was almost satiated, its rate was very low. The record at B is that which the animal made after one day of starvation and is approximately the rate maintained under the usual feeding method. The remaining records are for the successive days of starvation until the animal reached its peak on the fifth day (curve F). This animal belongs to the first group spoken of above and did not survive to give a record on the day following his peak.

Figure 4 gives some of the significant measurements on individual rats. The maximal rates are presented in terms of responses per hour on the day at which a peak was reached. The time to death is given as the number of days of starvation after which records were obtained. "Six days before death" means that the rat was dead on the seventh experimental day after food was withdrawn.

<sup>2</sup> With the 'usual feeding method' each rat is allowed access to the food for 1½ hours each day after the experimental period. The food used is Purina Dog Chow in large checkers. The small pellets used for re-inforcement were manufactured from this commercial food.



## DISCUSSION

A comprehensive investigation has been conducted in the Columbia University laboratory with the aim of ranking various drives in order of strength<sup>3</sup>. Since it is necessary that all drives be measured in comparable units, the maximal strength of each drive was ascertained by comparing the strength of a conditioned response based upon the drive with an opposed response of supposedly constant

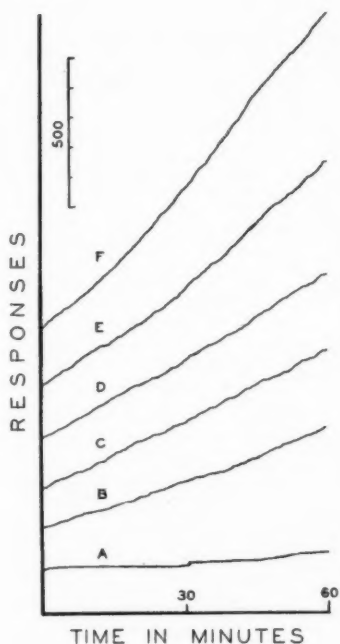


FIGURE 3  
A Representative Series of Records for One of the Rats in Group A. The record at A was taken after twenty-four hours of continuous access to food. Records B, C, D, E, and F follow at twenty-four hour intervals during starvation. The slight acceleration in Curves E and F is not typical.

strength. The drives were ranked on the basis of the maximal strengths so obtained. The course of the change in strength of each drive was followed by using separate groups of animals with varying degrees of deprivation. For example, in the investigation of hunger (experiments by Warner) six groups of twenty rats each were used. One group was measured after no days of starvation, another after

<sup>3</sup> See Warden, C. J., *Animal motivation: experimental studies on the albino rat*. New York: Columbia University Press. 1931.

two days, and so on for three, four, six, and eight days of deprivation. For male rats the group which had had four days of deprivation exhibited the largest number of responses prepotent over the opposed response. Measured with the present method the hunger drive reaches its maximum on the fifth day of deprivation (see Figure 1). The difference of one day may be caused by the fact that it was

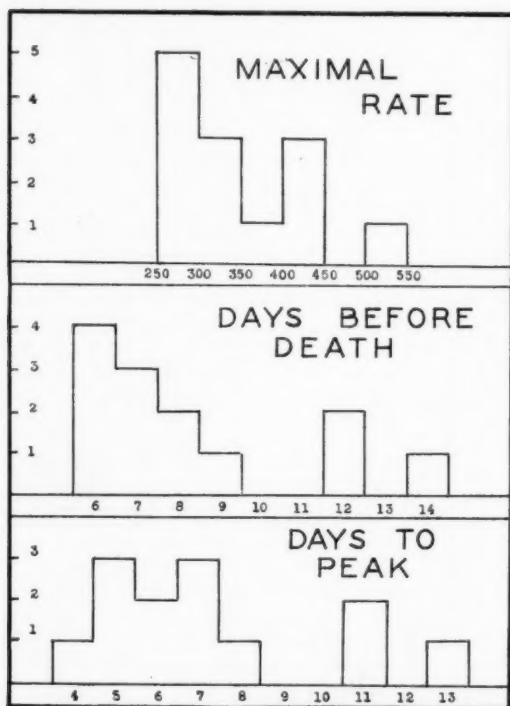


FIGURE 4

*Distributions of Maximal Rates, Times to Death, and Times to Peak.*

necessary in the present experiment to give a small amount of food for reinforcement. In general, the results check rather closely.

It is significant, however, that in the present experiment the measure obtained from averaging the group to represent the maximal drive is depressed. This is presumably also true of the Columbia

experiments. There are individual differences with reference to the point at which the rats reach their maximal drive during the period of deprivation. For example, in the experiment cited, some of the rats which were starved for four days had probably reached their maximal drive before the test period and some certainly reached it afterwards. The fourth day happens to catch more of the animals at or near their maximal drive than any other period used. An inspection of the data from the present experiment shows that the animals ranged from the fourth to the thirteenth day of starvation in reaching their peak. The mean is at 7.3 days and the median is 7. A comparison of the height of the peak in Figure 1 with the height of the peaks in Figure 2 will illustrate the depressing effect which the averaging of the group without respect to individual maxima has upon that peak.

This difficulty would not be serious if the measurements of all drives were affected in the same way, but unfortunately this is not the case. There are certain conditions under which the depressing effect will be minimized. (1) If the drive rises very rapidly to a peak (cf. thirst) the method of averaging groups will catch a great many more animals at or near their peak than would be the case if the drive rose slowly to a climax as in the case of hunger. (2) If the drive is maintained at the peak for a relatively long time, the chances of catching all animals at or near a peak value are very good. An example is the maternal drive which is probably maintained at its maximal level for a number of days while a litter is young.

This criticism of the use of one measurement per rat, and of the necessary averaging of group values in determining the course of a change in drive would, if true, invalidate a ranking of drives in the order of strength. Suppose that one is comparing hunger and thirst. The measure of thirst closely approximates the true maximal strength of that drive but the measure of hunger is considerably below the value actually obtaining in individual cases. It may be that the hunger drive is actually weaker than the thirst drive; if so the method has exaggerated the difference. Or it may be that the hunger drive is actually stronger than the thirst drive, but because the mean for the hunger drive has been depressed, it appears to be weaker. If maximal drives are to be compared in strength, the comparison should be based upon the mean individual peak.

#### SUMMARY

The course of the change in hunger during starvation was followed by examining the rate at which a rat responded to a lever when a response was reinforced with a small pellet of food every four

minutes. Measurements were made for one hour at twenty-four hour intervals. The mean rate for a group of thirteen rats reached a peak at five days of starvation. The individual records showed greater peak rates reached at from four to fourteen days. The mean rate was found not to be a reliable indication of the extent or the course of hunger in the individual. The typical curve for a single rat shows a steady rise throughout the greater part of the period before death. The ultimate drop is precipitous and coincides with a drop in bodily temperature and the general debilitation of the rat.

